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ANIMAL WASTE REUSE -- NUTRITIVE VALUE AND POTENTIAL PROBLEMS FROM FEED ADDITIVES

A REVIEW

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U.S. DEPARTMENT OF AGRICULTURE

Prepared by
Animal Science Research Division
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United States Department of Agriculture

ANIMAL WASTE REUSE -- NUTRITIVE VALUE AND POTENTIAL PROBLEMS FROM FEED ADDITIVES: A REVIEW

INTRODUCTION

During the 1960's, there has been a drastic change in the production of livestock. No longer are farms with a few head each of cattle, chickens, sheep, and swine as important in livestock production as they once were. Instead large specialized livestock production farms and, to a certain extent, corporations involving even a larger working capital have emerged in their place. The transition has not been without its problems. Nutrition and animal husbandry have been able to keep pace, and specialized knowledge and skills are available to answer related questions arising in this area. On the other hand, animal waste management appeared to be adequate but was repudiated by court decisions for lack of adequate research.

In a 1965 report of the environmental pollution panel to former President Johnson, the committee summarized the situation[1/]:

> "The problem of agricultural waste disposal has grown to such dimensions that probably the major unsolved issue in the confinement housing of livestock and poultry is the handling and disposal of manure. The magnitude of the problem may be visualized in simplified terms by comparing the wastes voided by man and the animals he raises. For example, a cow generates as much manure as 16.4 humans, one hog produces as much manure as 1.9 people, and seven chickens provide a disposal problem equivalent to that created by one person. As a result, farm animals in the United States produce 10 times as much waste as the human population."

Removal and disposal of waste is only one problem of animal production. With the trend toward confinement housing and larger concentrated production, management must be constantly aware of diseases that could destroy the entire operation. To guard against such a chance, producers have used more medicinal or related compounds, such as drugs, hormones, antibiotics, at prophylactic levels and for longer periods of time than at therapeutic levels of short duration. The problem then arises concerning the constant use of these compounds. How much, if any, passes through the animal and appears in the fecal material? If the waste is disposed of on land for crop production, what is the possibility of these compounds, in their entirety or as metabolites, becoming concentrated in the plant products harvested for feed and then being recycled in the animal? For consumer safety and before court rulings or laws are passed prohibiting use of medicinals or related compounds in livestock feeds, answers to the above proposed questions are urgently needed.

[1/] Restoring the Quality of Our Environment. The White House, pp. 170-171, November 1965.

This is a report of literature on the nutritional value of animal wastes and the potential problems that may occur when compounds other than nutrients are added to animal feeds. The literature on the potential problems from feed additives for poultry, swine, and ruminants for purposes of this report are the non-nutritive feed additives as listed by Scott, Neisheim, and Young (1969). They are as follows:

Pellet binders
Flavoring agents
Enzymes
Antibiotics, arsenicals, nitrofurans, (low level feeding)
Antifungals
Broad-spectrum, absorbable antibiotics (high level therapeutic use)
Chemicals used to potentiate curative properties of antibiotics
Coccidiostats
Worming drugs
Antioxidants
Carotenoid sources
Hormones
Reserpine, aspirin, and tranquilizing drugs
Larvicides

FEEDING VALUE OF ANIMAL WASTES

L. W. Smith[1/]

Digestibility of Cellulose Remaining in Ruminant Feces

Fiber in diets for ruminants is not digested to the maximum possible extent during the initial pass through the digestive tract. McAnally (1942) suspended oat straw and oat straw fecal residues in silk bags in the rumen of sheep. He observed 52 percent digestion of the original straw and an additional 12 percent digestion of fecal residues. Apparently, about 6 percent of the original straw fiber escaped digestion upon the initial pass through the sheep.

Bentley, Quicke, and Moxon (1958) reported that in vivo cellulose digestibility of soybean hulls was approximately 37 digestibility units lower than that obtained by in vitro methods. These authors suggest that too rapid passage caused the lower than potential digestion of cellulose from soybean hulls. Protein content (10 percent) was not apparently limiting cellulose digestion. At the Ohio Station Johnson, Scott, Moxon, and Bentley (1959) reported on the fecal cellulose digestibilities from sheep: soybean hulls, 76.52 percent; bromegrass hay, 5.25 percent; orchardgrass hay, 5.34 percent; alfalfa, 16.01 percent; and corn silage, 28.98 percent. The digestibility of fecal cellulose could be reduced by limiting feed intake. These two reports emphasized that sizable quantities of cellulose escape digestion in the ruminant under certain feeding regimes. Certain other nutrients, such as starch, must also escape digestion when a major component of the ration and when these nutrients are consumed at high levels of intake.

Wilkins (1969) also observed that forage cellulose was incompletely digested when suspended in the rumen in silk bags, even after unusually long periods of time. However, the extent of digestion under these conditions had proceeded further than in vivo digestion coefficients. Smith, Goering, and Gordon (1969) found the digestibility of fecal cellulose from orchardgrass hay fed cattle to be 34 percent when fed back to sheep at 25 percent of total dry matter (DM) intake. This level of fecal cellulose digestibility is within the range reported by McAnally (1942), Bentley, Quicke, and Moxon (1958), Johnson, Scott, Moxon, and Bentley (1959), Wilkins (1969), and Smith, Goering, and Gordon (1969) when using in vitro fermentation techniques.

Reports made by McAnally (1942), Dehority and Johnson (1961), and Wilkins (1969) led Waldo, Smith, and Cox (1969) to consider feed cellulose as two definable fractions--potentially digestible and indigestible. In such a model, the digestible cellulose appearing in the feces is part of the potentially digestible which escaped digestion. This is the cellulose which

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[1/] Research Dairy Husbandman, Dairy Cattle Research Branch, Animal Science Research Division, Agricultural Research Service, U.S. Department of Agriculture, Beltsville, Maryland 20705.

is digested when recycled or fermented in vitro. The potentially indigestible does not digest upon recycling or when fermented in vitro unless chemically treated to hydrolyze the lignin-polysacchride complex (Smith, Goering, and Gordon 1970).

The amount of cellulose that might possibly be digested upon recycling of ruminant feces could vary from 5 to 70 percent of that excreted. The level of theoretically digestible cellulose in feces appears to be related closely to the particle size initially fed and the compositional makeup of the ration. The particle size and makeup in turn influence the relative rates of passage and digestion.

Feed Reuse of Ruminant Manure

Feeding feces is by no means a new concept, even though it has only recently received publicity due to public concern as it fits in the overall picture of environment pollution abatement. Early in the 1940's cow manure was looked upon as a source of B-complex vitamins. Hammond (1942) reported on studies in which cow manure was used as a source of certain vitamins for growing chickens and later (Hammond, 1944) where cow manure or dried rumen contents was substituted for alfalfa meal in poultry diets. Bohstedt, Grummer, and Ross (1943) used cattle manure as a carrier of B-vitamins in rations for pigs. Lillie, Denton, and Rind (1948) demonstrated that cow manure contained a growth factor giving essentially the same gain response in chicks as crystalline B_{12}.

Anthony and Nix (1962) reported a study for which one of the objectives was to develop an effective means of disposing of organic residues voided by confined cattle through refeeding. This early study involved the feeding of washed wet fecal residues. Excellent gains (3 lb./day) were obtained for the three yearling fattening steers in the trial with 40 percent of the feed coming from washed fecal residue. No outward symptoms of harm nor difficulties in consumption were observed. Additional trials with wet fecal residue were conducted at Auburn University (Anthony, 1966) where gains of 3.60 lbs./day were obtained with Holstein bulls.

This practice was abandoned (Anthony, 1966) in favor of whole feedlot feces recycling. Combining feedlot feces with concentrates (40:60 ratio) was not a satisfactory practice based on animal weight gain and carcass grade. Blending fresh manure with high energy feeds lowered performance and digestion coefficients. It was theorized that manure contained a growth depressing factor since no intake and palatability problems were encountered. However, washing and heat treatment rendered feedlot cattle manure a useful feed for cattle by lowering the basal feed dry matter required per unit gain.

A later approach was to combine feedlot manure (57 parts) and ground Bermudagrass hay (43 parts) for making a high dry matter silage (Anthony, 1966, 1967, 1968, and 1969). Manure from all-concentrates had no nutritional advantage over manure from animals fed haylage for making the high dry matter

manure silage. Dry matter, crude protein, and cellulose digestion coefficients were essentially the same for the two manure sources as measured with steers. The manure-Bermuda haylage also maintained ewes in better physical condition with less total dry matter than when only Bermudagrass hay was fed.

Anthony (1967, 1968) developed the "Wastelage Concept" for effectively using feedlot manure as a feed. His reports (1967, 1968, and 1969) indicate success based on the equal or nearly equal daily gains, lower parakeratosis, and equal carcass grades (choice). Wastelage was also used successfully for ewes and beef cattle kept for reproduction. Low birth weights of lambs were improved by vitamin A injections. Cattle performed as well on wastelage as they did on corn silage. However, both groups were supplemented with a protein-mineral-vitamin A mix.

Only one-half of the daily manure excreted could be reused in grain: manure rations (Anthony, 1970). Little difference was found in nutrient value between cooked and washed manure. High grain rations containing wet manure were consumed well. These rations supported gains similar to cattle fed feeds without manure, although the total daily dry matter intakes were increased for manure-fed groups.

All-concentrate feedlot manure has been fed to pullets (6 weeks of age) and during laying at 10, 25, and 40 percent replacement levels for milo in a basal mix where milo represented approximately 70 percent of the basal ration (Durham, Thomas, Albin, and others, 1966). Manure was air-dried and ground before being mixed in the rations. Increased manure feeding resulted in increased feed consumption, but there were no significant differences in egg production or mortality. In another experiment, digestibility-metabolism and fertility were measured in hybrid pullets. The ten-percent manure treatment produced significantly more eggs. Digestibility of dry matter, energy, and ether extract, nitrogen retention and level of consumption were significantly different for each level of manure fed. No differences were found in fertility due to ration.

Catfish have been successfully raised on diets in which 50 percent of the ration was feedlot manure (Durham, Thomas, Albin, and others, 1966), where care was taken not to deplete the oxygen supply in the pond. Manure-fed fish made the more rapid growth during the early part of study than they did later in the study.

Some work has been reported in which yeast was grown on fluidized and aerated cattle manure (Anthony, 1969; and Singh and Anthony, 1968). Lignified fiber was removed and discarded. The solubles (68 percent of the original manure) were fed to rats. The rats developed diarrhea (Singh and Anthony, 1968) which was attributed to the high mineral content.

Ammonification of anaerobically fermented feedlot manure increased protein (CP) from 17 to 48 percent and was as acceptable to lambs as was ammonium lactate(Moore and Anthony, 1970).

Smith, Goering, and Gordon (1969) measured the influence of chemical treatments on digestibility of ruminant feces. Treating orchardgrass and alfalfa cow feces with sodium hydroxide and sodium peroxide resulted in large decreases in fibrous content. Cell wall (CW) digestibility was increased severalfold as measured by an in vitro fermentation technique.

Sheep consumed corn silage rations containing 25 percent of the total DM as either untreated or 3 percent sodium peroxide-treated orchardgrass cattle feces as well as they did an all corn silage ration (Smith, Goering, and Gordon, 1969). Addition of 3 percent sodium peroxide to feces increased average DM, 29; nitrogen, 25; CW, 55; cellulose, 41; and hemicellulose, 90 digestibility units over that of the untreated feces. Body weights of the sheep remained unchanged throughout the experiment.

Feed Reuse of Poultry Litter

Many popular articles (Johnson, 1957; Camp, 1959; Anonymous, 1966 (Feedlot) 8:59; Hardy, 1965; Anonymous (Feedstuffs), 1967; and Verbeck, 1960) have appeared in farm magazines concerning the use of poultry litter in ruminant feeding programs. These articles usually convey some university data, but more often are testimonials by successful and enthusiastic litter feeders. Apparently, chicken litter is attractive as a feed primarily because it is a cheap nonprotein nitrogen source (9-33 percent CP equivalent) and not because it is more nutritional than commercially available and more aesthetically acceptable feeds.

Chance (1965) reviewed the subject and concluded, "Poultry litter can be used satisfactorily as a ruminant feed." In this country experiments with poultry litter have been confined to its use for beef cattle and sheep. Those areas with large numbers of chickens (Arkansas, Georgia, Florida, and Virginia) have conducted and reported experiments concerning the use of poultry litter as feed for ruminants. The use of poultry litter in cattle and sheep diets is not confined to the United States.

The use of poultry litter in feeds for cattle and sheep has been reported from South Africa (Verbeck, 1960), Canada (Anonymous,Feedstuffs, 1967), and Australia (McInnes, Austin, and Jenkins 1968). In England, dried poultry feces is being marketed as TOPLAN at $28.80 per ton (Zindel and Flegal, 1969). The composition is given at 42.3 percent DM, 26.6 percent CP, 28.7 percent carbohydrate, and 15.2 percent ash. The British Agricultural Research Council has suggested the following feeding rates for beef and sheep production: 50 percent TOPLAN to 50 percent barley, and for dairy cattle 25 percent TOPLAN to 75 percent barley.

Poultry litter has been successfully used as a protein supplement for gestating-lactating ewes (Noland, Ford, and Ray, 1955), wintering cattle (Fontenot, Drake, McClure, and others, 1964; Ray and Child, 1964) growing wethers (Harms, Simpson, Waldroup, and Ammerman, 1968), and fattening cattle (Southwell, Hale, and McCormick, 1958; Ray, 1959; Fontenot, Drake, McClure, and others, 1964; Fontenot, Bhattacharya, Drake, and McClure, 1966). Ray (1959) observed that litter became dusty when ground and resulted in lower levels of consumption by the cattle.

Noland, Ford, and Ray (1955) concluded that broiler house litter would replace conventional protein supplements in the rations of both gestating-lactating ewes and fattening steers. Nearly equal rates of gain were obtained for chicken litter-fed steers and cottonseed meal-fed steers by increasing total feed intake by 15 percent for the former.

Noland, Ford, and Ray (1955) cited Belasco (1954) as having reported that rumen organisms utilize uric acid. Even though Belasco (1954) makes such a statement he presents no supporting data. However, Looper and Stallcup (1958) demonstrated that ammonia is released from chicken litter at about the same rate as from Morea when incubated with rumen inoculum.

Analysis of the litter used in Arkansas trials (Noland, Ford, and Ray, 1955) showed that of the total nitrogen present, 19.2 percent was uric acid nitrogen. Poultry droppings are reported to contain 63 to 87 percent uric acid N (Eno, 1962). When litter is wet, uric acid decomposes rapidly to urea and ammonia; and some ammonia is lost. Artificial drying causes additional loss of ammonia. Chance (1965) indicated that one of the major problems associated with inclusion of litter in rations for ruminants is the high variability of compositions as regards chemical composition. Table 1 was presented by Chance (1965) to demonstrate range in compositions.

Many factors contribute to the variation in litter composition (Chance, 1965; El-Sabban, Long, Gentry, and Frear, 1969). Those mentioned were: (1) Type of bird (layer or broiler); (2) type of litter (such as corncobs, peanut hulls, rice hulls, sawdust, shavings, bagasse, and oat hulls or straw); (3) ventilation of house; (4) litter management; (5) amount of litter used; and (6) number of birds and length of time a flock is kept on the litter. Brugman, Dickey, Plummer, and Poulton (1967) showed that sterilizing litter lowered its feed value. There are probably other factors as yet unconsidered.

Brugman, Dickey, Plummer, and Poulton (1964) reported protein digestibility of layer litter to be 77.8 percent with beef bulls. Fontenot, Drake, McClure, and others (1964), Bhattacharya and Fontenot (1964, 1965), and Fontenot, Bhattacharya, Drake, and McClure (1966) determined the protein digestibility of peanut hull broiler litter in sheep when 0, 25, 50, and 100 percent of the dietary nitrogen was supplied by the litter. Nitrogen digestibility declined with increases of litter in the ration. Fifty and 100 percent litter resulted in 68.3 and 57.7 percent nitrogen digestibility, both coefficients being significantly lower than 71.3 to 70.4 percent attained for the control and 25 percent litter diets.

TABLE 1.--Composition of chicken litter

Chance (1965)

Item	Broiler house		Laying house	
	Average	Range	Average	Range
	percent	percent	percent	percent
Moisture	23.50	27.23- 15.37	28.85	41.38- 18.47
Protein	28.74	32.66- 24.44	11.95	14.98- 9.38
Fat	2.53	4.00- 1.75	0.61	1.02- 0.32
Fiber	21.38	28.36- 12.75	16.80	22.50- 12.56
Ash	8.25	10.54- 6.53	19.65	27.06- 16.61
N.F.E.[1/]	17.86	20.90- 15.01	22.12	26.02- 16.48
E.C.P. - N.P.N.[2/]	4.84	7.13- 2.44	1.51	2.81- 1.19
Lignin	11.76	16.61- 7.41	7.85	12.72- 5.60
Ca	1.33	1.82- 0.87	5.56	8.18- 4.28
P	0.99	1.30- 0.71	1.09	1.47- 0.91
Kilocalories/gram	3362	3483 -2876	2243	2836 -1803

1/ Nitrogen free extract
2/ Estimated crude protein-nonprotein nitrogen

Crude protein digestion coefficients (73 to 75 percent) were essentially the same for peanut hull and wood shaving broiler litter at 25 and 50 percent substitution (Bhattacharya and Fontenot, 1966). Brugman, Dickey, Plummer, and Poulton (1964) reported values as high as 78 percent crude protein digestibility for bulls when layer litter was fed. This small difference is probably of little consequence to the animal and reflects some of the differences in composition pointed out by Chance (1965). They reported that greater differences may be expected in crude fiber digestibility, 63 to 91 percent, due to the use of different litters.

Nitrogen retention in wethers was found to be significantly lower when 100 percent of the nitrogen was supplied by broiler litter (Fontenot, Bhattacharya, Drake, and McClure, 1966; Bhattacharya and Fontenot, 1965). Bhattacharya and Fontenot (1965) showed that nitrogen from broiler litter was efficiently used by sheep fed semipurified rations when 25 to 50 percent of the total dietary protein was supplied by litter.

Disease has not been reported as associated with the feeding of poultry litter. This may be related to careful handling (heat treatment in many cases) under the supervision of research personnel. Bradley and Russell (1964) pointed out possible hazards - some of these include possible toxicity to ruminants of drugs, pesticides, and feed additives used for poultry production. Hardware in litter, transfer of various diseases (tuberculosis), and mold are possible. On the other hand, Leibholz (1969) has suggested that the transfer of disease from poultry to ruminants is unlikely.

Digestive disturbances have been attributed to litter feeding (Chance, 1965). Diarrhea at the beginning of litter feeding appeared in fattening cattle in Virginia and bloat appeared in some cattle in Arkansas when fed a rice hull base litter. Both problems were overcome by feeding some long hay.

Problems such as those mentioned above motivated the Department in 1965 to make a policy statement unfavorable to the use of poultry litter as feed for beef cattle. More recently, though, research toward recycling of agricultural waste has been encouraged.

Feed Reuse of Poultry Feces

Quisenberry and Bradley (1968) reported one of the first experiments designed to test the feasibility of feeding poultry feces to poultry. Layer feces and natural mixtures of litter and droppings from different sources were incorporated into rations at 10 and 20 percent levels. Seven diets were formulated to be equicaloric and isonitrogenous. With the exception of one diet, the nutrient recycled diets were equal to or superior to the basal or control for maintaining body weight, hen-day egg production, feed efficiency, and egg size. Recycled nutrients were reported to have had no adverse effect on bird mortality or egg taste tests.

Similar results have been reported by Zindel and Flegal (1969) at Michigan State University for growth as well as egg production trials. These trials involved dehydrated poultry waste (free of litter) at various levels of inclusion from 5 to 40 percent. Reduced body weights and lower feed efficiency resulted for growing birds fed greater than the 5 percent level. Up to 40 percent inclusion had no adverse effect on egg production, shell thickness, or Haugh score, even though feed efficiency was lower.

Zindel and Flegal (1969) carried out a second recycling of poultry feces with no change in egg production. A third recycling is planned. Consumer taste panels were unable to detect any differences in tastes of eggs. This is in agreement with the results of Quisenberry and Bradley (1968).

Neither of these two papers dealing with recycling of poultry feces to poultry mentioned the transfer of chemical residues to the final product. Zindel and Flegal (1969) reported that there is no apparent microbiological contamination of eggs produced from diets containing feces and that pathogens have not been found in poultry manure dried for diet inclusion.

The house fly (Musca domestica Linnaeus) have been used to reduce the moisture content of poultry excreta (Calvert, Martin, and Morgan, 1969a, 1969b; Calvert, Martin, and Morgan, 1970; and Miller and Shaw, 1969) and produce a high protein feed supplement (Calvert, Martin, and Morgan, 1969a).

Several trials were conducted at Pennsylvania State University (Long, Bratzler, and Frear, 1969) to evaluate feeding and nutritive value of poultry feces. Treatments involved hydrolysis with steam, cooking under 30 pounds pressure, or drying in a commercial drier.

Cooked or hydrolyzed poultry feces were compared with soybean oil meal as nitrogen sources in rations for wethers. The only difference was a lower nitrogen digestion (5-9 digestibility units) for the poultry feces. However, when fattening steers were fed hydrolyzed poultry wastes, dried poultry wastes, or soybean oil meal, rate of gain, feed efficiency, and carcass grade were not significantly different. No problems were experienced in feeding poultry waste nor were levels of DDT, DDE, TDE, or arsenic levels in the carcass of consequence.

Dugan, Golueke, and Oswald (1969) have designed a pilot system for utilizing poultry feces as nutrients for algae. The algae would then be used in ruminant feeds. If the system is operational, results on the evaluation of the feeding value of algae have not been reported as yet.

Feeding of Miscellaneous Wastes

Ronning, Bankston, and Berousek (1957) and Tucker, Glenn, and Roberstad (1956) found no response from inclusion of dried rumen contents in the diet of dairy cattle and sheep. Likewise, no benefit was obtained when dried rumen contents were used in a milk replacement ration for young calves (William and Jensen, 1954). Kamstra, Simmer, and Embry (1959) found no stimulatory effect

in vitro or in vivo (rate of gain, feed efficiency, feed consumption, or digestibility) for dried rumen contents.

Swine waste subjected to aerobic digestion in an oxidation ditch was fed to rats at 24.5 and 49 percent addition to a corn-soybean meal diet by Harmon, Jensen, and Baker (1969). The lower level of waste supported adequate gain and feed efficiency but the higher level was unsatisfactory. Earlier work by Diggs, Baker, and James (1965) showed that low levels (15 percent) of dried pig feces in conventional swine finishing rations supported similar weight gains and feed efficiency as the basal. Higher levels reduced both feed efficiency and gain.

A ration for sheep in which 18 percent of the nitrogen was supplied as dried activated sewage sludge (Hackler, Neumann, and Johnson, 1959) was found equal, as measured by nitrogen retention, to a soybean oil meal and a urea-containing ration. The digestibility was 12 units lower, but this was compensated by its higher biological value.

Algae grown on sewage has been fed to rats (Cook, Lau, and Bailey, 1963), chicks (Grau and Klein, 1957), pigs, cattle and sheep (Hintz, Heitman, Weir, and others, 1966). Algae containing 51 percent crude protein, 6 percent crude fiber, 6 percent ether extract, and 6 percent ash was fed to swine, cattle, and sheep (Hintz and coworkers, 1966). The ration had to be pelleted to prevent sorting, otherwise the algae was refused. Protein was 73 percent digestible when fed to cattle and sheep, but only 54 percent digestible when fed to pigs. Algae-supplemented barley made an adequate growing-finishing ration for pigs. When fed to lambs, algae-alfalfa pellets resulted in higher gains than alfalfa pellets alone. The authors indicate that even though the cell wall is resistant to digestion, the high protein, carotene, and mineral content make algae a potentially valuable livestock feed.

FECAL RESIDUES FROM FEED ADDITIVES--POULTRY

C. C. Calvert[1/]

To keep pace with the increased demand for eggs and poultry meat the feed manufacturers and producers have used more and more feed additives. These may be for disease control, using relatively high levels, or they may be used as stimulants for increased growth or egg production. The general attitude of most feed manufacturers and producers is that the therapeutic levels of coccidiostats, antibiotics, and arsenicals are essential for maintaining our current high levels of egg and meat production. However, there is a concern today with what these additives may contribute to air, soil, and water pollution after they have performed whatever function they may have in the animal body. The scope of the problem is difficult to determine, since there are no accurate estimates available on the amounts of the various feed additives in feeds. What must be done then is to try to evaluate the potential hazard and have this information available.

Wadleigh (1968) estimated that the waste from poultry farms amounted to 48 million tons annually. No doubt the amount has increased since then. The amount of coccidiostats, arsenicals, and antibiotics present in poultry waste is unknown, but the potential hazard from even small amounts of additives from such enormous quantities of waste may be very great.

The nonnutritive feed additives commonly found in poultry feed some of which may be a hazard to the environment will be discussed below.

Pellet binders.--Commonly used materials are pulverized bentonites, liquid or solid byproducts of wood pulp industry consisting mainly of hemicelluloses and lignins or both, and Guar meal. None of these materials would seem to be a hazard to the environment.

Flavoring agents.--There are chemical compounds that may decrease feed consumption, but none have been found that will increase feed consumption. For this reason no flavoring compounds are added to poultry feeds. Certain natural feed ingredients such as barley, rye, and buckwheat are not particularly palatable to the chicken, so in the future, flavoring agents may be used. None of these materials would seem to be a hazard to the environment.

Enzymes.--There are very few preparations used because of doubtful benefit. These protein preparations would probably not be a pollution problem.

Antibiotics, arsenicals, and nitrofurans (low level feeding as growth adjuvants).--These are the same compounds that are used for the treatment of specific diseases, but when fed at low levels (5 to 10 mg./kg.) may have

[1/] Research Poultry Husbandman, Poultry Research Branch, Animal Science Research Division, Agricultural Research Service, U.S. Department of Agriculture, Beltsville, Maryland 20705.

growth promoting properties. These three classes of compounds probably have greater potential for contributing to pollution than any other nonnutritive feed additives. These three classes will be considered individually.

A. Antibiotics. There are four commonly used antibiotics: chlortetracycline, oxytetracycline, penicillin, and bacitracin. There are others, but for purposes of this discussion these four present the greatest possible hazard.

There are few references that could be found on the intestinal degradation and absorption of any of these antibiotics. Felson, Wieser, Meredith, and Winter (1965) reported on the absorption of chlortetracycline when fed at a level of 200 mgs./lb. and found the amounts absorbed quite variable. No exact figures were given and it was not possible to calculate the amount that would have been excreted. Bare, Wiseman, and Abbott (1965) studied low levels of bacitracin and penicillin and found that after continuous feeding of 11 mg./kg. of bacitracin and 44 mg./kg. penicillin there was a marked difference in the amount of these two compounds in the intestine, and the level of bacitracin remained the same. It appeared that bacitracin was much more resistant to deactivation than penicillin. No comparable studies were found for oxy- and chlortetracycline. From these results, it would appear that some antibiotics are excreted in fairly large quantities and others are not. Which ones are, and the exact amounts, remain unknown.

There is evidence that soils contain natural levels of a wide variety of antibiotics(Margard, Peters and Litchfield, 1968). How much dietary antibiotics would increase this level of soil antibiotics is as yet unknown.

If antibiotics are to continue to be added to feed at low levels as growth adjuvants, an accurate measure of the intestinal deactivation, types of metabolites and their activity, the amount of various antibiotics in fecal material, the contribution of antibiotics in animal wastes to the overall level in the soil, and the action of soil types and soil bacteria on antibiotics is needed to determine the contribution of antibiotics as feed additives to the overall problem of pollution.

B. Arsenicals. Frost, Overby, and Spruth (1955) reviewed the literature up to that time on the use of arsenic for animals. This review revealed that an arsenic containing compound, atoxyl, was successfully used in 1907 in treating spirochetosis in hens. Other studies since then have demonstrated that phenylarsonic compounds, were effective in treating coccidiosis in chickens, Morehouse (1949), and blackhead in turkeys, Barger and Card (1949), Morehouse and McGuire (1950).

Morehouse and Mayfield (1946) first discovered the growth-stimulating effects of 3-nitro-4-hydroxyphenylarsonic acid. Since that time many studies have been conducted on the use of arsenicals as growth promotants in poultry with varied results. These have been reviewed by Frost, Overby, and Spruth (1955), Ewing (1963), and Scott, Nesheim, and Young (1969).

In order to evaluate the potential contribution of arsenicals to soil and water pollution, it might be well to know which compounds are approved for use by the FDA and the use level in the diet, either as growth promotants or in the treatment of diseases. The following is a list of arsenic containing compounds that are FDA approved and listed in the 1967 Feed Additive Compendium:

(1). Arsanilic acid or sodium arsanilate
Use level - 0.005-0.01 percent (45-90 gm./ton)
Claims - Stimulates growth and improves feed efficiency and pigmentation in growing chickens and turkeys; increases egg production and improves feed efficiency in chickens (breeders and layers.) Improves bloom and feathering.

(2). Arsenobenzene
Use level - 0.002 percent
Claims - Prevents coccidiosis. Also, may be used with various antibiotics at this level for stimulating growth, preventing CRD, nonspecific enteritis, blue comb and synovitis, and, when combined with antibiotic plus dienestrol diacetate a level of .007 percent promotes distribution of fat.

(3). 3-Nitro-4-hydroxyphenylarsonic acid
Use level - 0.0025-0.005 percent
Claims - Stimulates growth, improves feed efficiency in broilers and layers, improves pigmentation and increases egg production. Also used in combination with coccidiostats (Amprolium, Zoaline, Ethopabate, Nitrophenol, Furazolidone, Nitrofuran, and Sulfaquinoxaline) to prevent coccidiosis and stimulate growth. Combinations of 3-nitro-4-hydroxyphenylarsonic acid and the antibiotics, penicillin, and bacitracin, may also be used to stimulate growth.

(4). 4-Nitrophenylarsonic acid
Use level - 0.01875 percent-0.025 percent
Claims - Prevents blackhead in turkeys and chickens. Stimulates growth when used with antibiotics (bacitracin, penicillin, chlortetracycline and streptomycin.

These are arsenic containing compounds used primarily as growth-stimulating compounds, but they may also be used in combination with other coccidiostats and antibiotics in the treatment of coccidiosis and other diseases of chickens and turkeys.

Some information is available on the distribution of the arsenicals after they have been ingested by chickens. Morrison (1969) reported on the distribution of arsenic from poultry litter in chickens, soils, and crops. The results of this study indicate that the broiler chicken may excrete as much as 88 percent of ingested 4-hydroxy-3-nitrophenylarsonic acid without any alteration of chemical structure. Other studies by Moody and Williams (1964a) have shown that 4-nitrophenylarsonic acid is largely unchanged in the gut as is arsanilic acid. (Moody and Williams, 1964; Overby and Fredrickson, 1963, 1965; and Overby, Bochieri, and Fredrickson, 1965.) The levels of arsenic fed in the study by Morrison (1969) were not known precisely, but the amount in the litter ranged from 15 to 30 p.p.m. In litter from birds where no arsenic was fed, the levels ranged from 0.1 to 2.6 p.p.m.

Fertilizing with poultry litter containing arsenic did not increase the soil, water, or forage level of arsenic. The rate of application was 4 to 6 tons per acre over a 20-year period. This rate of application would add as much as 100 grams of arsenic per acre per year, but the level found in soil was 1.8 p.p.m. This level was the same as for soils that had received no arsenic. Herbicides have been shown to leave as much as 550 p.p.m. of arsenic in the soil (Williams and Whetstone, 1940). To produce this same level in the soil, 2200 tons of poultry litter per acre would have to be applied.

C. Nitrofurans. The common compounds now in use in the treatment of a number of diseases and in promoting growth are: Furazolidone, Nitrofurazone, and Nihydrazone. These compounds are combined with each other and with other coccidiostats, antibiotics, and arsenicals. There is no information available on the extent of their use, but since they are very successful in the control of blackhead, coccidiosis, and salmonella infections in turkeys and chickens, they are probably being used quite extensively. As to their metabolites, Paul (1956) writes that end products vary depending on the type of nitrofuran. Nitrofurazone breaks down to four end products besides the original compound. He does not indicate the amount of each, but does state that none have bacteriostatic properties. Nitrofurans do not accumulate in the tissues and large quantities may be excreted by the urine. Nothing was said about the type of compound excreted. There is a possibility that these compounds may appear in fairly large quantities in poultry manure, but what effect they might have as a pollutant is not known. Because of their bacteriostatic function in the gut, it is possible that they might affect soil bacteria. Whether the concentration found in manure would be great enough to affect soil bacteria is not known.

Antifungal additives.--These are compounds, such as quaternary ammonium, sodium propionate, and nystatin, that may be added to feeds to prevent mold growth. The amounts, however, are small and it is unlikely that they are a hazard to the environment.

Broad spectrum, absorbable antibiotics.--These antibiotics are the same ones as mentioned previously, but they are used at higher levels for short periods. Since these compounds would be used for the treatment of diseases and are not fed continuously, they probably would not be a pollution hazard.

Coccidiostats and worming drugs.--The 1967 Feed Additive Compendium lists 17 compounds or combinations of compounds that are cleared for use in the treatment of coccidiosis and 17 single compounds and combinations for the treatment of intestinal worms. Some of these compounds contain arsenic; some are antibiotics alone or in combination with other compounds. Other compounds used are the sulfa drugs, sulfaquinoxaline and sulfanitran. Not much is known about these compounds once they leave the gut and even in the gut their mode of action is not well understood. The same statement could apply to the worming agents. Fortunately, most of these compounds are only fed for a short period of time and, since they are used primarily for disease prevention, it is unlikely that they are a hazard to the environment.

Antioxidants.--There are three commonly used antioxidants - ethoxyquin, BHT, and BHA. Ethoxyquin (6-ethoxy-1,2,dihydro-2,2,4-trimethylquinaline) is widely used in poultry feeds at a level of 0.0125 percent. BHT (butylated hydroxytoluene) and BHA (butylated hydroxyanisole) are also used but not to the extent of ethoxyquin. Calvert (1962) in a review for the Cornell Nutrition Conference states that antioxidants function to prevent the oxidation of fat in feed and may act as biological antioxidants in the tissue to replace vitamin E in the prevention of certain of the vitamin's deficiency symptoms. For this reason, that is, the antioxidant may be largely absorbed by the chicken and is changed chemically in the prevention of oxidation of fats, antioxidants would not be considered to be a pollution problem.

Carotenoid sources.--At present, all of these sources are naturally occurring compounds and are almost all metabolized by the chicken. There are some synthetic carotenoid pigments on the market, but they have not been cleared by FDA for use in animal diets (Scott, Nesheim, and Young, 1969).

Hormones.--Hormones are not widely used in poultry feeds, but on occasion some may be added for specific purposes. Iodinated casein has been used to simulate the action of thyroxine. Thyrouracil, while not a hormone, may be added to diets to suppress thyroid activity and increase fertility in hens (Marks, 1969). Dinesterol diacetate is added to some broiler chick diets at a level of 0.0023 percent in the finishing diets. This compound has estrogenic activity and if it appears in fecal matter it could be a problem. There is no information available concerning the extent of its use, however. There are several hormones that can induce molt in hens, but the Feed Additive Compendium does not list any as being sanctioned by the FDA.

Reserpine, aspirin and tranquilizing drugs.--Reserpine has been approved by the FDA for use in improving the performance of chickens under stressful environmental conditions. The levels are 0.0001 percent for broilers and 0.002 percent for hens. (It is used in turkey diets as treatment for aortic rupture.) Levels in this instance are 0.0001 percent for a period not

to exceed 5 days before the chickens are 4 weeks of age and 0.002 percent for continuous feeding after the chickens are 4 weeks of age. Ewing (1963) discusses the use of reserpine quite extensively, but the exact amount currently used and the possible metabolites are not known. More information is necessary before any definite statement about its potential as a pollutant can be made.

Aspirin and tranquilizing drugs have been studied but their benefits have been slight and they are not listed by the FDA for use as feed additives.

Larvicides.--There are no larvicides currently used as poultry feed additives.

FECAL RESIDUES FROM FEED ADDITIVES--SWINE

L. T. Frobish[1/]

With the trend toward confinement rearing, swine waste disposal has limited and will continue to limit any further intensification of pork production. Kesler (1966) reported that hog wastes totaled 9.3 percent of the body weight of hogs per day in enclosed confinement buildings. He further commented that a growing-finishing pig, 18 to 100 kg., will produce an average of about 5.7 liters per day or 680 liters of waste in a 120-day finishing period. With the trend toward confinement feeding of 3,000 to 10,000 pigs per year, this amounts to a total waste volume of 2.04 to 6.80 million liters per year. On the basis of total solids, the average daily production would approximate 3 kg. of solids per pig for a total solids production of 30,000 kg. per swine farm. A potential hazard exists from drugs, hormones, minerals, antibiotics, etc., being excreted in the feces or urine and subsequently being taken up by plants and reappearing in the swine feed via the plants producing the commonly used cereal grains.

Scott, Nesheim, and Young (1969) prepared an extensive list of feed additives. Discussion will be limited to the major items associated with swine production. They are: antibiotics, arsenicals, copper, nitrofurans, sulfonamides, and hormones.

[1/] Research Animal Husbandman, Swine Research Branch, Animal Science Research Division, Agricultural Research Service, U.S. Department of Agriculture, Beltsville, Maryland 20705.

Antibiotics, Arsenicals, Copper, Nitrofurans and Sulfonamides

Many compounds have been used for the treatment of specific diseases in swine but when incorporated into the diet at low levels may have growth promoting properties.

Antibiotics

About one-half the penicillin appearing in the blood serum is reversibly bound to plasma proteins. Penicillin does not appear to show any affinity to any tissue component. Except for the excretory organs, its concentration in tissues is lower than in the blood. Excretion of penicillin occurs mainly via the kidneys and to a lesser extent by the liver where it reaches the intestine via the bile. There is some excretion via the hair follicles to the skin surface. Penicillin is removed from the tissues very rapidly as a result of fast renal elimination. Part of the penicillin is degraded during its passage through the body to the metabolite penicilloic acid where it appears in the urine.

Streptomycin is poorly absorbed from the intestine and has shown some affinity for connective tissue, cartilage, and endothelium. It is excreted mainly by the kidneys. Chromatography of mouse urine from mice injected with dihydrostreptomycin revealed no breakdown products. It is believed that the action of dihydrostreptomycin is similar to streptomycin.

The tetracyclines appear to be taken up by tissues, with particular affinity for the bones and teeth. This is probably related to the property of tetracycline to bind calcium by a chelating mechanism. There is also an accumulation in the kidney. Tetracyclines are very stable and almost all excretion is via the urine.

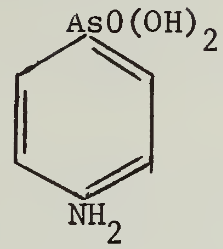
There is little available information on the metabolites of antibiotic degradation, their excretion, and possible distribution in the soil and finally into plants.

Arsenicals

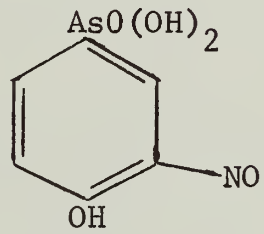
Arsenicals have been used as tonics in the practice of veterinary medicine for a long time. The therapeutic use of arsenic trioxide (As_2O_3) was described by Fowler and the 1 percent solution bearing his name has been in common use since it was propcsed in 1786. Hundreds of arsenical compounds have been tested for their ability to control parasitic diseases. The various compounds differ not only in their effectiveness against parasites but also in their toxicity to the host.

Four arsenical compounds that have been used quite extensively in livestock feeds are:

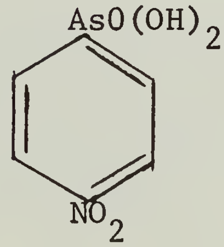
Arsanilic acid (p-aminophenyl arsonic acid)



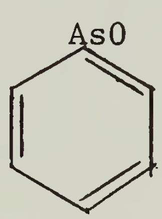
3-Nitro-4 hydroxyphenyl arsonic acid



4-Nitrophenyl arsonic acid



Arsenobenzene (phenyl arsenoxide, trivalent form)



Arsanilic acid, the most common arsenical compound employed in swine diets, is the primary intermediate used in the manufacture of most other arsenicals.

Arsanilic acid is recommended as a feed additive for swine at a level of 0.005 to 0.01 percent (50 to 100 p.p.m.) of the diet to promote increased weight gains and feed efficiency (Buck, 1969). These levels also aid in the prevention of infectious and parasitic diseases. Hanson, Carpenter, Aunan, and Ferrin (1955) reported that, when levels of arsanilic acid of 0, 33, 66, and 99 mg./kg. of diet were fed, tissue retention of arsenic was related to the level fed. The greatest amount of arsenic was retained in the liver and the next greatest amount was retained in the kidneys. However, withdrawal of arsanilic acid from the ration a few days before slaughter greatly reduced the amount of arsenic remaining in the tissues.

The margin of safety for arsanilic acid is quite high. Harding, Lewis, and Done (1968) fed arsanilic acid at levels ranging from 0.67 to 22 mg./kg. of diet and found no adverse effects on the pigs. Ten days after cessation of arsanilic acid feeding, arsenic levels in the urine were still above those for control pigs. On the other hand, arsenic levels in tissue had fallen to normal in some of the pigs.

Feeding of arsanilic acid results in accumulation of arsenic in the liver, kidney, and spleen and to a lesser amount in the muscle, fat, and blood. However, the level of retention may be influenced by the type of diet, method of feeding, water intake, or all three. Vorhies, Sleight, and Whitehair (1969) reported that arsenic stored in the liver generally increased with water deprivation from 1.8 p.p.m. in pigs receiving water ad libitum to 3.30 p.p.m. for pigs receiving 240 ml. of water daily. Bridges, Hale, Kunkel, and Lyman (1954) have reported similar findings. If the diet is composed of certain fish products, in particular fresh water fish and crustaceans, there may be a large accumulation of arsenic in the tissues. Underwood (1962) reported from 4 p.p.m. to as high as 174 p.p.m. arsenic in certain types of fish. Only if fish products account for a large percentage of the diet would the arsenic content have any effect on tissue accumulation of arsenic.

Tatum (1940) concluded that arsenic administered in the inorganic form is excreted almost entirely via the kidneys, while organic arsenicals, especially the trivalent form, are excreted by way of the feces and kidneys. Overby and Frost (1960) conducted a study to determine both the excretion rate and route of arsenic in swine fed arsanilic acid at levels ranging from 0 to 99 mg./kg. of diet. They also measured the daily excretion of arsenic as elemental arsenic and as arsanilic acid. The results of their experiment suggested that the major route of arsenic excretion in the pig is via the feces. Only when the level of arsanilic acid in the diet reached the 66 mg./kg. level was there an apparent increase in urine arsenic content. Of the total arsenic voided in the feces, 5 to 10 percent was arsanilic acid. Arsanilic acid was not detected in the urine. In a subsequent experiment, they noted that by 3 to 4 days post-arsanilic feeding, fecal excretion of arsenic was drastically reduced irrespective of the level fed.

Peoples (1969) concluded that the commonly held idea that arsenic is a cumulative poison is without foundation except in the case of the rat. He also reported on the metabolic action of arsenic and noted that trivalent arsenic reacts with the sulfhydryl groups of enzymes and proteins. On the other hand, pentavalent arsenic uncouples oxidative phosphorylation since unstable arsenylated oxidation products undergo irreversible hydrolysis without the formation of a high energy phosphate bond.

To reiterate, the problem of arsenic may not be its continual low level feeding but one of constant use of arsenicals in the feed, excretion of arsenic via the feces, spreading of the fecal material on land used for crop production, and subsequent accumulation of arsenic in plants used for livestock or human consumption. From the consumer viewpoint, this would be very undesirable.

Tatum (1940) observed that injection of neoarsphenamine into pregnant rats increased the arsenic content of the fetuses as term approached. More recently, Peoples (1964) reported there was a possibility for arsenic to enter into cattle via cottonseed meal used as a protein supplement.

Harmon, Becker, Jensen, and Baker (1969) analyzed the two primary ingredients of swine rations, corn and soybean meal, for trace mineral content and reported no value for arsenic. Soils differ greatly in arsenic content, ranging from 0.3 to 40 p.p.m. for samples obtained in the United States and Mexico. Contamination of soils with arsenic may produce vegetation with higher arsenic content than that found in natural soil, but plant growth is itself limited before injurious concentrations are absorbed (Williams and Whetstone, 1940).

If the excretion figures cited by Overby and Frost (1960) are correct, a pig receiving an arsanilic acid level of 66 mg./kg. of feed voids 12.3 mg. of arsenic daily. Then for a 120-day finishing period, this would amount to about 1.5 g. of arsenic per pig. Three thousand market pigs would excrete 4.5 kg. of arsenic for the entire feeding period. It is doubtful whether this amount when spread on crop land would be harmful. Frost (1953) reported as much as 182 kg. of $Ca_3(AsO_4)_2$ per acre had been used as a pesticide and had no apparent effect on plant growth. The total arsenic concentration per acre with this application would approximate 68 kg. Arsenic in the soil is dissipated by the normal slow processes of leaching and reduction to volatile derivatives of arsine. The proper use of arsenic acids does not appear to significantly increase the normal daily intake of arsenic via plant proteins.

Copper

For more than a decade, results of research on copper supplementation in pig diets have shown an improvement in weight gains and feed utilization caused by high levels of copper. Approximately one-third of the pigs produced in the United Kingdom are fed high levels of copper. It is doubtful if this level of copper supplementation has been attained in the United States. However, with the increasing cost involved in swine production, a savings in feed cost (which represents 70 percent of the total cost of production) would increase the profit margin. In 1967, the swine industry consumed over 40 million tons of feed. The use of copper as a growth stimulant could result in a $25 million savings annually to the swine industry.

In a recent review on copper research, Wallace (1967) summarized the benefits of high levels of copper in the diet. A brief summary is presented below:

1. On the average, for all ages of pigs, copper supplementation improved gains 8.9 percent and feed efficiency 3.2 percent.

2. A response was observed to levels of copper ranging from 50 to 375 p.p.m.

3. Copper sources, such as copper sulfate, copper sulfate pentahydrate, copper oxide, copper carbonate, copper chloride, and copper methionine, all proved effective supplements.

4. Copper is a toxic substance and the margin of safety between beneficial and harmful levels is not as great as for other trace elements. Iron, zinc, molybdenum, and, to a certain extent, calcium supplementation can affect the copper storage, excretion, or both. No toxicity problems are anticipated with copper levels as high as 250 p.p.m. when thoroughly mixed with the diet.

Although copper supplementation appears to be highly beneficial, consideration must be given to its excretion and possible harmful effects in the waste material. Very little research on the excretion of copper has been done. Studies with stable and radioactive copper have demonstrated that the absorption of copper is poor for all species. It appears that about 5 to 10 percent of the copper in ordinary diets is absorbed and retained in the body (Underwood, 1962). Absorbed copper is transported in the blood plasma loosely bound to the plasma protein, serum albumin. Excretion of copper is via the bile into the feces with very small amounts passing directly from the plasma into the urine. The biliary system is the major pathway of absorbed copper excretion in the pig.

Castell and Bowland (1968) have estimated the amount of ingested copper retained in the body of pigs by feeding either a basal diet containing 5 p.p.m. of copper or a basal diet supplemented with 0.1 percent copper sulfate pentahydrate ($CuSO_4 \cdot 5H_2O$). Expressing retention as a percent of intake, pigs fed the basal diet retained from 23 to 44 percent of the ingested copper as feed intake increased from 1.27 to 2.83 kg. daily. However, with pigs receiving supplemental copper, the percent retention decreased from 32 to 22 percent as feed intake increased. On the high level of copper, the average amount of copper in the fecal material would be approximately 350 mg. per day.

There is considerable evidence that copper has a beneficial effect in swine diets. However, data on excretion of copper and its subsequent effect on environment are very limited. There is evidence that copper is highly corrosive to certain metals used in the construction of swine shelters.

Nitrofurans

The parent compound for many nitrofurans is furfural. Nitrofurans are broadly grouped into two classes. Class A comprises the simpler nitrofurans where the R-group bonded to the furfural ring may be an alkyl, acyl, hydroxyalkyl, or carboxyl group bonded together with esters or other derivatives. This group would include nitrofuraldehyde and its diacetate, methyl nitrofuryl ketone, 5-nitro-2-methylfuran, nitrofurfuryl alcohol and its

esters, nitrofuroic acid and its amide and esters, and similar compounds. Class B includes derivatives of nitrofuraldehyde or nitrofuryl ketones where condensation has occurred between the carbonyl group and a nitrogen-containing molecule.

Only a small percentage of administered nitrofurans appear unchanged in the urine (Paul, Austin, Paul, and Ells, 1949). Compounds of Class A are oxidized to nitrofuroic acid and excreted in this manner. Nitrofuroic acid shows no activity in vivo. The amount of nitrofurans excreted in the urine varies from trace amounts with furazolidone to 25 percent with nidroxyzone, 45 to 50 percent with nitrofurantoin and up to 75 percent with nitrofuroic acid. Fecal excretion is very small and amounts to only 0.5 to 10 percent of the dose administered.

There is a void in information on the uptake of excreted nitrofurans by plants and their possibility of returning to the animal via the plant. In addition, there has been little research on the stability of nitrofurans in the soil following excretion directly onto the soil or by the spreading of accumulated waste material. Some of the nitrofurans excreted are bacteriostatic and bacteriocidal against both gram positive and gram negative organisms (Beckman, 1958).

Sulfonamides

Thousands of sulfonamide derivatives are known today but only a few are active in combating infection. The rate of absorption and excretion varies with the different sulfonamides. Sulfonilamide, sulfamethazine, sulfamerazine, and sulfathiazole are absorbed very rapidly.

Sulfonamides diffuse through most of the body tissues except bone and fat. They are capable of passing through the blood-brain barrier and are found in the cerebrospinal fluid.

Acetylation accounts for a majority of the inactivation sulfonamides undergo in the body. Acetyl derivatives are therapeutically inactive and toxic. Sulfonamides can also be deactivated by conjugation to form glucuronates and sulfates and by oxidation. They are bacteriostatic in all instances except in the urinary tract where because of the poor medium for bacteria and the high concentration of the sulfonamides they are bacteriocidal. Sulfonamides are therapeutically active only against those bacteria that synthesize their own folic acid.

There is limited information on sulfonamide excretion rate, uptake, and incorporation by plants, and possible entry into animals.

Hormones

Until recently, incorporation of estrogenic hormones into swine rations has not been shown to be of much benefit. Baker, Jordan, Waitt, and Gouwens (1967) have demonstrated that a combination of diethylstilbestrol (DES) and

methyltestosterone may have some potential benefit with respect to improving carcass composition. More recently Echternkamp, Teague, Plimpton, and Grifo (1969) have shown that DES may be of value in suppressing the odor in meat sometimes obtained when boars are finished for market. However, little information is available on the excretion of DES by swine. Swine following cattle implanted with DES may accumulate DES in their body tissues. Therefore, the excretion of estrogenic activity by cattle and the subsequent uptake by crops is a potential problem to the swine industry.

Smith, Wilder, and Williams (1948) examined the urinary excretion of estrogen following administration of either stilbestrol, hexestrol, dienoestrol, or stilbestrol glucuronide. They reported that with rabbits about 35 percent of the administered estrogen could be accounted for in the urine. That there may be a species difference in excretion of estrogens was evident from the lower estrogen recoveries obtained with cats.

Twombly (1951) concluded that the major route of excretion of DES is via the bile into the feces. He fed mice a ration containing highly active DES labeled with radioactive C^{14}. Approximately 70 to 85 percent of the DES was eliminated in the bile while only 15 to 30 percent appeared in the urine. Less than 0.2 percent of the C^{14} administered appeared in the expired air.

Story, Cheng, Pauls, and Hale (1957) fed levels of 1 and 2 mg. per day of stilbestrol to lambs and observed estrogenic activity in both the urine and feces as noted by the uterine response of mice. Approximately 48 percent of the stilbestrol was recovered in the feces and 32 percent in the urine. The larger the amount fed, the greater the excretion rate in the urine.

The amount of estrogenic activity in the feces may be influenced by the method of administering the DES. Callantine, Stob, and Andrews (1961) reported that cattle given 10 mg. of DES orally per day excreted significantly more estrogen than did heifers treated subcutaneously with 24 or 36 mg. of either DES or hexestrol, respectively. Hexestrol implantation did not result in greater fecal estrogen elimination than in animals not given supplementary estrogen.

Cheng, Story, Culbertson, and Burroughs (1952) extracted clover and alfalfa hays and found biologically active estrogenic substances. Implantation of DES as a synthetic and additional estrogenic material failed to stimulate lamb gains above the gains obtained by animals receiving clover hay with estrogenic activity, where the source of the activity of the hay or the form or substance giving estrogenic activity was not ascertained. However, the estrogenic activity may have come from the feces of DES implanted cattle that had been spread on crop land.

Broom, Gurd, Harmer, and Randall (1961) treated strips of arable land with hexestrol at the rate of 10 and 50 μg./kg. harrowed into the top 10 cm. of the soil. They observed that hexestrol disappeared from the soil within weeks. At the low level of application, no hexestrol was detected after 4 weeks, but with the higher level, 8 weeks were required before hexestrol was

not detectable in the soil. Estrogenic activity could not be demonstrated in either grass or clover grown on treated plots when cut at 7, 17, or 22 weeks after sowing. In cattle, hexestrol is excreted as a glucuronide which is more water soluble than hexestrol. Both compounds, however, tend to leach deeper than 10 cm. into the soil.

Glascock and Jones (1961) also reported that a grass-clover mixture grown on plots dressed with hexestrol demonstrated no estrogenic activity. They concluded that leaching, evaporation, or both, accounted for very little of the hexestrol removed from the soil. There was no appreciable change in the specific radioactivity of soil treated with labeled hexestrol during a 3-month period.

Diethylstilbestrol may have some potential in swine diets; however, there is very limited information on its excretion pattern. Excretion of estrogens is quite variable from species to species. Little uptake of estrogens has been demonstrated in plants grown on soils treated with estrogen compounds. Thus, the possibility of the pig receiving estrogen activity either via crops grown on land where fecal material from estrogen implanted cattle has been spread or via pigs following treated cattle in the feedlot appears to be highly doubtful.

FECAL RESIDUES FROM HORMONES AND ANTIBIOTICS--BEEF CATTLE

D. A. Dinius[1/]

Hormones

The interest in hormones excreted by animals which may be recycled through plants and back to man or animals is with the natural and synthetic estrogens, androgens, and progestins. This discussion deals only with these. Other hormones, such as follicle stimulating hormone and luteinizing hormone, may be present in animal excreta but they occur in small concentrations and are readily biodegradable; thus, they are of little ecological concern.

Estrogenic activity has been detected in the urine and feces of cycling cows and increasing amounts of estrogenic activity are found in the excreta with advancement of pregnancy. Breed (Guernsey, Holstein, Jersey), age, and live weight of cows are not related to excretion rate of estrogens when the

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[1/] Research Animal Husbandman, Beef Cattle Research Branch, Animal Science Research Division, Agricultural Research Service, U.S. Department of Agriculture, Beltsville, Maryland 20705.

excretion rate is adjusted to an equal body weight basis. From 0.2 to 2 mg. of estrogens are excreted per day in the urine of the cycling cow, the excretion rate varying with the stage of the estrous cycle (Mellin and Erb, 1966). Average total urinary estrogen excretion per day per 500 kg. of live weight during pregnancy varies from 7 mg. at 110 days pregnancy to 70 mg. a few days prior to parturition (Erb, Randel, Mellin, and Estergreen, 1968). There is a small but steady increase in the excretion rate of estrogens during the first 7 months of pregnancy and then a rapid increase during the last 2 months. Estrone and 17 α-estradiol are the major excretory products and one or two other compounds having estrogenic activity are often found. Most urinary estrogens are excreted in a conjugated form, primarily with glucuronic acid, while perhaps only 5 percent is excreted in the free form. For a detailed discussion of the relative amounts of the excreted estrogenic compounds at various stages of gestation, see Erb, Randel, Mellin, and Estergreen (1968) and for a general review of estrogens, see Mellin and Erb (1965).

Although most research has been done with urinary excreted hormone, the major route of estrogen excretion is via the liver into the bile and subsequently into the intestinal tract and defecated with the feces. Cattle excreted two to three times as much radioactivity in the feces as in the urine after being intravenously injected with labeled estrogens (Hunt, Legault, and Herrick, 1961; Mellin, Erb, and Estergreen, 1965). The major fecal estrogenic compound is 17 α-estradiol. Peak fecal and urinary excretion of intravenously administered natural estrogens comes at 5 to 10 hours after dosing. From 20 to 24 percent of the administered dose had been excreted during the first 12 hours and from 29 to 33 percent by the end of 3 days (Hunt, Legault, and Herrick, 1961; Mellin, Erb, and Estergreen, 1965).

Approximately twice as much of a given dose of diethylstilbestrol (DES) is excreted as compared with a dose of natural estrogens. Cattle treated orally with 10 mg. of DES daily excreted a uniformly significant amount of estrogen in the feces throughout a 168-day treatment period. The combined daily fecal and urinary excretion ranged from 55 to 84 percent of the dose and averaged 63 percent calculated as DES (Callantine, Stob, and Andrews, 1961; Melampy, Gurland, and Rakes, 1959). Apparently the greater the amount of DES fed, the greater the proportion excreted in the urine. Lambs fed 1 mg. of DES per day excreted 51 percent of the compound in the feces and 25 percent in the urine. At the 2 mg. level 45 percent appeared in the feces and 39 percent in the urine (Story, Cheng, Pauls, and Hale, 1957). From 20 to 30 percent of the DES fed is metabolized or in some manner inactivated.

Heifers subcutaneously implanted with 24 or 36 mg. of DES excreted significant amounts of estrogens for 50 to 60 days (Callantine, Stob, and Andrews, 1961). Feces of lambs implanted with a 12 mg. pellet of DES contained greater amounts of estrogen one month after implantation than immediately after treatment. However, subsequent to this, there was a gradual reduction in the amount of fecal hormone (Stob, 1956). This pattern of DES excretion parallels the anabolic effect of the implanted hormone.

In the research with DES, 20 to 30 percent of the synthetic hormone given to animals was not recovered. The structural configuration of the excreted compounds was not determined but activity was measured by bioassay. Consequently, the quantity of metabolites of DES excreted with reduced estrogenic activity or without activity can not be ascertained. The more recent work with natural estrogens included chromatographic as well as radioisotope procedures to isolate and quantitate excretory products.

The average dairy cow excretes approximately 30 mg. of estrogens per day in urine and feces. On a dry matter basis, the hormone concentration would be 5 mg. of estrogens per kg. of waste material. Spreading of this manure on soil at the rate of 12 metric tons dry matter per hectare (nearly 5 tons per acre) would result in the application of 60 g. of estrogens per hectare (24 g. per acre). In making these calculations the biological activity of the various excreted estrogens has been ignored and it is assumed that there is neither degradation of estrogens in the manure nor loss of hormone by evaporation or runoff.

A steer fed 10 mg. DES per day will excrete about 75 percent of the dose in an active form. Thus, manure from DES fed steers spread on soil at the rate given above would result in less than one-third the estrogenic contamination given above. Excreta of implanted steers spread on soil at this same rate would result in less than 2 g. of DES per hectare.

The fecal route of excretion appears to be even more of a factor with progesterone. Within 12 hours after administering radioactive progesterone-4-C^{14} to a lactating cow, 45 percent of the dose was excreted in milk, 3.16 percent was excreted in urine and 49.84 percent was excreted in feces within 48 hours (Williams, 1962). All the radioactivity of a dose of C^{14}-labeled 16-alpha-dihydroxy-progesterone acetophenide (DHPA, an estrus synchronization compound) was recovered in the feces (97.9 percent) and urine (2.1 percent). None of the radioactivity was measured in the respired carbon dioxide and most of the radioactivity was obtained in the feces and urine during the first 7 days post administration (Rumsey and Schreiber, 1969). The biological activity of the excreted compounds was not determined in either of the above studies. There have been few studies to quantitate progesterone excretion.

One problem in obtaining valid progesterone excretion data is the apparent conversion of progesterone to androgens in the manure. Androgenic activity has been demonstrated in cow feces but not in bull feces (Riley and Hammond, 1942). There is some evidence that the feces must be incubated with its microbial population before androgenic activity can be detected, indicating that the androgen is not a direct excretory product of the cow. The addition of progesterone before incubation of feces increased the resultant androgenic activity. Quantitative data are lacking but the androgenic activity is sufficient to be easily detected by the chick comb growth assay (Lueker, Butterworth, and Schulz, 1960).

There have been experiments with other anabolic compounds (melengestrol acetate, zearalanol, resorcyclic acid lactone) and with anti-androgenic compounds. As yet, no excretory studies with these materials have been reported.

The stability and ultimate fate of estrogenic compounds in the soil has received some study. In one experiment (Hacker, Cruea, Shimoda, and Hopwood, 1967) excreta from a steer that had been implanted with labeled DES was mixed with sandy loam soil and this was maintained in a greenhouse for a few months. Six radioactive products were extracted from an acid (pH 6.5) sandy loam soil, none of which had estrogenic activity; whereas, three radioactive products were extracted from the alkaline (pH 7.5) soil, one of which was DES. DES was the minor fraction but another of the products also had estrogenic activity. Thus, the stability of estrogenic compounds in the soil may vary with soil characteristics.

Little translocation of estrogenic compounds was found in several studies (Glascock and Jones, 1961; Glascock and Hewitt, 1963; Hacker, Cruea, Shimoda, and Hopwood, 1967). Glascock and Jones (1961) found no appreciable change over a 3-month period in the specific activity of soil dressed with labeled hexestrol, showing that neither hexestrol nor the decomposition products had been lost by evaporation or by leaching. Only 9 to 11 percent of the radioactivity in extracts of soil made 3 months after contamination was in the chemical form of hexestrol. In another study with the top 10 cm. of soil contaminated with hexestrol (Broom, Gurd, Harmer, and Randall, 1961) samples of soil taken between 10 and 30 cm. depth 11 weeks after treatment contained hexestrol, indicating some leaching. No estrogenic activity could be detected in the upper layer of soil 4 weeks after treatment at the rate of 10 μg. per kg. but 8 percent of the estrogenic activity remained 4 weeks after treating soil at the rate of 50 μg. per kg. Marked local variations in concentration of estrogenic activity in soil was noted by Glascock and Jones (1961), probably as a result of the random dropping of excreta by cattle which had been in the test field prior to the study.

Time and the presence of plants may favor the conversion of hexestrol to its derivatives. Less hexestrol and different derivatives were found in soil in which plants had grown than were found in soil of control plots (Glascock and Hewitt, 1963). Several plants (ryegrass, fescue, clover, wheat, pinto beans, mustard, lettuce, cabbage, radishes, onions, and potatoes) have been grown on soil to which known quantities of hexestrol or DES had been applied (Broom, Gurd, Harmer, and Randall, 1961; Glascock and Jones, 1961; Glascock and Hewitt, 1963; Hacker, Cruea, Shimoda, and Hopwood, 1967). Minute quantities of radioactivity above background could be detected in plants grown on soil containing labeled DES. Hacker, Cruea, Shimoda, and Hopwood (1967) found only lettuce roots and radish leaves of plants grown on alkaline soil had uterotropic activity. In research using nonlabeled hexestrol (Broom, Gurd, Harmer, and Randall, 1961; Glascock and Jones, 1961) no estrogenic activity was detected in any of the crop samples taken at intervals over 4 or 5 months, indicating that the hexestrol content was less than the minimum (20 μg./kg. fresh weight) detectable by the techniques used. Studies with labeled hexestrol (Glascock and Hewitt, 1963) found uptake through the plant roots was between 0.06 and 0.04 percent of the radioactivity, depending on root medium and plant species.

The conclusion from these experiments is that uptake of synthetic estrogens from soil by roots of plants is insufficient to be harmful to man or animals consuming them. A dose of 1 μg. of hexestrol per kg. body weight is detrimental to man. The maximum concentration of exogenous estrogenic activity found in plants in these studies was about 0.03 μg./kg. of fresh weight. At that concentration a 50 kg. person would have to consume 1700 kg. of food per day to be adversely affected by the hormone.

One must keep in mind, however, that certain plants contain endogenous estrogenic compounds. Plant estrogenicity may be sufficient to adversely affect fertility of grazing animals (Engle, Bell, and Davis, 1957). As much as 200 mg. of coumestrol per kg. of alfalfa meal has been reported (Oldfield, Fox, Bahn, and others, 1966). In some situations the estrogenicity of plants can be used to advantage. Organoleptic tests consistently demonstrated improved tenderness and juiciness scores from lamb roasts of animals finished on high-coumestrol diets.

Antibiotics

Certain antibiotics are frequently added to the high-grain rations commonly fed to finishing beef cattle. The following review summarizes some of the research that has been conducted with these antibiotics, particularly in reference to the potential for recycling through feedstuffs.

When administered orally, both chlortetracycline and oxytetracycline are readily absorbed by monogastric animals (Spector, 1957). Rapid disappearance of chlortetracycline from the rumen also has been observed. However, the disappearance may have been the result of biodegradation within the rumen as well as absorption from it. Lodge, Miles, Jacobson, and Quinn (1956) found only 10 percent of an initial dose of antibiotic in the ruminal fluid of cows 4 hours after ingestion, and Bush, Jacobson, and Hartman (1957) reported rapid disappearance of chlortetracycline from the ruminal fluid of young calves. An organism capable of growing in the presence of large amounts of chlortetracycline was isolated from the ingesta of cows. This organism was more abundant in cows receiving the antibiotic than in cows receiving none, suggesting that it may be capable of destroying chlortetracycline and thus accounting for the rapid disappearance of the antibiotic. However, no direct evidence for ruminal degradation of chlortetracycline has been found. Several possible fates other than biodegradation for chlortetracycline after it enters the rumen have been suggested, including absorptions into the blood stream, absorption by or adhesion to the microbial cells, and passage into lower parts of the digestive tract. The relative importance of these routes for removal of the antibiotic from ruminal fluid has not been reported.

Absorption of orally administered chlortetracycline into the blood stream of ruminants has been shown by Rusoff, Fussell, Hyde, and others (1954) and Hester, Landagora, and Rusoff (1954) who found small amounts of the antibiotic in the bile and urine of calves. The extent to which absorption occurred was not reported. Both chlortetracycline and oxytetracycline were readily absorbed by monogastrics after receiving oral doses. Excretion was

primarily via the urine. As much as 8 percent of a dose of oxytetracycline was recovered in the active form in the urine of man 24 hours after dosage (Goldberg, 1959). Orally administered bacitracins or streptomycin were primarily excreted in the feces of man and little or no measurable blood concentrations were noted (Spector, 1957).

The use of antibiotics in agronomic and horticultural studies has been primarily in the area of disease control. However, these compounds also have been found to elicit effects upon plants. Both growth inhibition and stimulation have been observed. For example, antibiotics have been reported to affect such plant processes as photosynthesis, pigmentation, polyphenolase activity, organic acid synthesis, and chromosomal behavior. The magnitude of the host response displayed seems to be dependent upon the plant species sensitivity, the specific antibiotic, and concentration used (Goldberg, 1959).

Antibiotics have been applied directly to soil in various plant disease control experiments. Some of the antibiotics are rapidly metabolized by soil microflora and many of them are inactivated by absorption by colloids in the soil (Martin and Gottlieb, 1955). The highly basic antibiotics such as streptomycin and the polypeptide antibiotics, such as the bacitracins, are inactivated in the presence of soil. The amphoteric tetracyclines, in either alkaline or acid forms, are absorbed by both illite and montmorillonite clays. The neutral antibiotics are more readily absorbed from soil through plant roots; however, the antibiotics commonly fed to cattle are not in this category.

The antibiotics of cationic and amphoteric nature remain active for comparatively short periods of time in soil. Streptomycin readily binds with clay, and all attempts to remove it by exchange with hydrogen ions were unsuccessful. Biological degradation of streptomycin in soil also has been reported (Parmer and Starkey, 1951). There have been reports of persistence of both streptomycin and tetracyclines in plants with the former probably the more stable. Oxytetracycline has been found in plants 8 weeks after treatment and streptomycin as much as a year after treatment (Alcorn and Ark, 1956); however, this research was done by spraying the antibiotics directly on the plants. Apparently plants will not absorb from the soil measurable quantities of the antibiotics commonly fed to cattle.

FECAL RESIDUES FROM LARVICIDES--POULTRY AND CATTLE[1/]

R. W. Miller[2/]

Many fly species are found around domestic animal manures. Those infesting cattle manure include the house fly, Musca domestica Linnaeus; the horn fly, Haematobia irritans (Linnaeus); the face fly, Musca autumnalis De Geer; and the stable fly, Stomoxys calcitrans (Linnaeus). Around poultry manure, fly pests, in addition to the house fly, are the little house fly, Fannia canicularis (Linnaeus); the coastal fly, Fannia fermoralis Stein; and the false stable fly, Muscina stabulans (Fallén). Additional species reported to be a problem around poultry wastes in Hawaii are Fannia pusio (Wiedemann), Chrysomya megacephalis (F.), and Parasarcophega arygrostoma (Robineau-Desvoidy) (Sherman, Ross, and Komatsu, 1962).

One of the best methods for control of these pests is through the use of larvicides, applied either directly to the manure, or as a feed additive.

Historical Development of Larvicides

The history of compounds tested as larvicides parallels the development of insecticides. Gallagher (1928) fed cows tannic acid, linseed oil, magnesium sulfate, and sodium chloride in an attempt to make their feces unfavorable for the development of horn fly larvae.

Knipling (1938) reported that phenothiazine administered to cows at the rate of approximately 100 mg./kg. body weight caused the manure from these cows to be toxic to horn fly larvae.

It was later reported that rotenone and zinc oxide when fed to cattle were effective horn fly larvicides (Bruce, 1942).

The use of chlorinated hydrocarbon insecticides as feed-additive larvicides was investigated by Eddy, McGregor, Hopkins, and Dreiss (1954). They found aldrin and dieldrin to be very effective larvicides against the horn fly, the stable fly, and the house fly when fed to cattle at a level of 25 p.p.m. Lindane fed at 100 p.p.m. was effective as a horn fly larvicide.

1/ Previously published in the Bulletin of the Entomological Society of America as Larvicides for Fly Control - A Review, by R. W. Miller, Vol. 16, No. 3, pp. 154-158, September 1970.

2/ Research Dairy Husbandman, Animal Science Research Division Agricultural Research Service, U.S. Department of Agriculture, Beltsville, Maryland 20705.

Sampson (1956) reviewed the use of various chemicals which have been recommended as house fly larvicides throughout the world. He also reported on certain insecticides, mainly chlorinated hydrocarbons, which he found to be effective house fly larvicides. The most effective of these were endrin, heptachlor, lindane, and parathion.

Non-Insecticidal Larvicides for Poultry and Cattle

In the late 1950's and early 1960's two compounds, not conventional insecticides, were tested as feed-additive larvicides. These were a boron compound, Polybor 3, and the pathogen *Bacillus thuringiensis* Berliner. Burns, Tower, Bonner, and Austin (1959) showed that Polybor 3 was an effective feed-additive larvicide against the house fly when fed to caged layers, however, boron residues appeared in the eggs and tissues of hens so treated. Harvey and Brethour (1960) found Polybor 3 to be larvicidal against the house fly when mixed directly with manure from a steer, however, there was no larvicidal activity in feces from steers fed up to 100 g. of Polybor 3 per day.

Hall and Arakawa (1959) showed that *B. thuringiensis* would kill house fly larvae, but not adults. Since that time, numerous workers have fed this pathogen to both poultry and cattle. Reduction in adult fly emergence when *B. thuringiensis* was fed to poultry has been reported (Briggs, 1960; Harvey and Brethour, 1960; and Burns, Wilson, and Tower, 1961). Burns and coworkers (1961), however, reported decreased feed consumption and egg production at concentrations of the pathogen which gave 97 percent control of fly larvae. Later reports (Sherman, Ross, and Komatsu, 1962 and Eversole, Lilly, and Shaw, 1965a) concluded that *B. thuringiensis* would not be an effective feed-additive larvicide for fly control around poultry manure.

In the first experiments conducted feeding *B. thuringiensis* to cattle, Dunn (1960) reported an 89 percent reduction in house fly emergence. Gingrich (1965) fed three different commercial preparations of *B. thuringiensis* to cattle for the control of the house fly, horn fly, and stable fly. Although there were differences between the preparations as well as in the susceptibility of three fly species, Gingrich concluded that the pathogen could effectively control the three species of flies just mentioned. Ode and Matthysse (1964), however, reported essentially no control of face fly larvae when *B. thuringiensis* was fed to cattle at levels of 30 mg./kg. body weight. Miller, Pickens, and Gordon (1971) have data showing almost no control of house fly larvae in feces from dairy cows fed similar levels of the same pathogen.

Organophosphorus Larvicides for Poultry

In 1959, organophosphorus insecticides began receiving a great deal of attention as possible feed-additive larvicides for the control of flies around both poultry and cattle operations. Table 1 lists insecticides referred to in this paper which do not have common names.

TABLE 1.--Insecticides mentioned which do not have common names

Compound	Chemical name
American Cyanamid 12008	O,O-diethyl S-isopropylthiomethyl phosphorodithioate
American Cyanamid 18706	O,O-dimethyl S-(N-ethylcarbamoylmethyl) phosphorodithioate
Azodrin	3-hydroxy-N-methyl-cis-crotonamide dimethyl phosphate
B 10046	S-p-chlorophenyl O-isopropyl (chloromethyl) phosphonodithioate
B 10119	O-isopropyl S-p-tolyl (chloromethyl) phosphonodithioate
Bay 21/200	O-(3-chloro-4-methylumbelliferone) O,O-dimethyl phosphorothioate
Bay 18510	O,O-dimethyl S-(phenyl) (carboethoxy) methyl phosphorothioate
Bay 18779	O-ethyl-O-isopropyl-O-phthaloximido phosphorothioate
Bay 22408	O,O-diethyl O-napthalimido phosphorothioate
Bay 25141	O,O-diethyl O-p-[(methyl sulfinyl) phenyl] phosphorothioate
Bay 29493	O,O-dimethyl O-(4-methylthio-m-tolyl) phosphorothioate
Bay 34098	O,(4-methylthio-m-tolyl) dimethyl phosphinothioate
Bay 37289	O-ethyl O-2,4,5 trichlorophenyl ethylphosphonothioate
Bay 37341	O,O-diethyl O-[4-(methylthio)-3,5-xylyl] phosphorothioate
Bay 37342	O,O-dimethyl O-(3,5-dimethyl 1-4-methylthiophenyl) phosphorothioate
Bay 62863	2,3-dihydro-2-methyl-7-benzofuranyl methylcarbamate
Ciodrin	alpha-methylbenzyl 3-hydroxycrotonate dimethyl phosphate
Dow ET-15	O-methyl O-(2,4,5-trichlorophenyl) phosphoramidothioate
Dowco 105	O-methyl O-(4-tert-butyl-2-chlorophenyl) ethylphosphoramidothioate
Dursban	O,O-diethyl O-3,5,6-trichloro-2-pyridyl phosphorothioate
G 30493	S-[[(3,4-dichlorophenyl)thio] methyl] O,O-dimethyl phosphorodithioate
Imidan	O,O-dimethyl S-phthalimidomethyl phosphorodithioate
Methyl Trithion	S-((p-chlorophenylthio)methyl) O,O-dimethyl phosphorodithioate
Nemacide	O-(2,4-dichlorophenyl) O,O-diethyl phosphorothioate
NIA 10242	2,3-dihydro-2,2-dimethyl-7-benzofuranyl methylcarbamate
Potasan	O,O-diethyl O-(4-methyl-2-oxo-2H-1-benzopyran-7-yl) phosphorothioate
Rabon	2-chloro-1-(2,4,5-trichlorophenyl) vinyl dimethyl phosphate
S 4087	O-p-cyanophenyl O-ethyl phenylphosphoniothioate
SD 8448	2-chloro-1-(2,4,5-trichlorophenyl) vinyl diethyl phosphate
R-3828	S-(p-chloro-alpha-phenylbenzyl) O,O-diethyl phosphorodithioate
V-C 3-668	O-methyl S,S-dipropyl phosphorotrithioate
Zytron	O-2,4-dichlorophenyl O-methyl isopropylphosphoramidothioate

Sherman and Ross (1959) showed that single doses of trichlorfon, malathion, ronnel, and Dow ET-15 fed to chicks caused greater than 90 percent mortality of house fly larvae in the feces. The duration of the toxicity of the feces was from 1 to 6 days. In a later trial, Sherman and Ross (1960) confirmed the larvicidal activity of trichlorfon, ronnel, and Dow ET-15 and in addition showed that coumaphos and diazinon were effective feed-additive larvicides. The amounts of these insecticides fed ranged between 89 and 220 p.p.m. of the total ration for the birds. All the compounds except ronnel and Dow ET-15 caused some mortality in the chicks or subclinical toxicity expressed as poor growth or decreased egg production.

Sherman and Ross (1961) tested the larvicidal activity of 23 insecticides when fed to chickens as single oral dosages, as feed additives, or as when administered via the drinking water. The most effective insecticides against house fly larvae when fed as single oral doses included Bay 22408, dimethoate, Dowco 105, dicapthon, and coumaphos. Feed additives which caused 80 percent or more mortality to house fly larvae included American Cyanamid 12008, American Cyanamid 18706, Bay 22408, Bay 25141, Bay 29493, dicapthon, dimethoate, and phosphamidon. The last two insecticides were the most effective larvicides when added to the drinking water of the chickens.

Complete control of house fly larvae was reported by Dorough and Arthur (1961) when broilers were fed Bay 22408, Bay 29493, Bay 34098, and Bay 37342 at levels of 50 p.p.m. Ronnel was effective at 200 p.p.m.

Sherman, Ross, and Komatsu (1962) and Sherman and Komatsu (1963) tested the effectiveness of various organophosphorus insecticides against house fly larvae and larvae from the three species mentioned earlier as being a problem in Hawaii. At concentrations between 40 to 100 p.p.m. of the ration, American Cyanamid 12008, Bay 22408, dimethoate, Bay 18510, and Zytron^{R} were effective larvicides for all four species. At the same concentrations propyl thiopyrophosphate, Bay 18779, and Methyl Trithion^{R} were effective against all species except _Fannia pusio_. Additional compounds which were effective against at least three of these Hawaiian fly pests were: Azodrin^{R}, chlorfenvinphos, Dursban^{R}, Nemacide^{R}, G 30493, V-C 3-668, Bay 37289, S 4087, B 10046, B 10119, NIA 10242 (Sherman, Komatsu, and Ikeda, 1967).

Certain of the more promising organophosphorus insecticides have been subjected to further testing either as a feed additive or as a direct application to poultry droppings. Eversole, Lilly, and Shaw (1965b) reported 91 percent mortality of little house fly larvae when hens were fed 125 p.p.m. coumaphos in the feed. Simco and Lancaster (1966) reported 87 percent control of house fly larvae when hens were fed 40 p.p.m. coumaphos. Loomis, Deal, and Bowen (1968b) demonstrated only 43 percent control of house fly larvae when hens were fed 60 p.p.m. coumaphos. Better control than this was obtained on the coastal fly and the black garbage fly, _Opyra leucostoma_ Wiedemann, but control of the little house fly and false stable fly was poor. Whether or not coumaphos will ever be cleared for use as a poultry feed additive is questionable because residues have been found in eggs 11 to 15 days after hens were fed 100 p.p.m. radiophosphorus coumaphos in their ration (Dorough, Brady, Timmerman, and Arthur, 1961).

Bell, Bowen, Deal, and Loomis (1965) showed that a dust made from diazinon 50 percent wettable powder and agricultural gypsum and applied to poultry droppings gave good control of the little house fly and the false stable fly but failed to control the house fly.

Loomis, Bramhall, and Dunning (1968a) and Loomis (1969) reported excellent control of house flies when Zytron was applied directly to poultry droppings. Control of the Fannia species was poorer with this insecticide.

Organophosphorus Larvicides for Cattle

As with poultry, many of the organophosphorus insecticides and a few of the carbamates have been tested as feed-additive larvicides for cattle. Eddy and Roth (1961) tested 25 compounds, mainly organophosphates, for this purpose and showed that Bay 22408, coumaphos, Bay 21/200, Potasan^R, Dow ET-15, and ronnel were all lethal to house fly larvae at levels of 5 mg./kg. body weight. Since Bay 22408 and coumaphos were effective at even lower levels (1 mg./kg. body weight) the authors just cited concluded that the control of feces-breeding fly larvae was not only possible but practical. Anthony, Hooven, and Bodenstein (1961) also showed that coumaphos and Bay 22408 when fed to cattle at a level of 1 mg./kg. body weight prevented the emergence of both house fly and face fly larvae. Ronnel fed at a level of 5 mg./kg. body weight was also lethal to larvae of both species.

Skaptason and Pitts (1962) reported coumaphos levels of 5, 10, and 50 p.p.m. of the ration caused high house fly larval mortality. Treece (1962, 1964) presented more evidence on the effectiveness of coumaphos, Bay 22408, and ronnel against face fly larvae. Additional compounds offering promise in this area included Rabon^R, SD 8448, chlorfenvinphos, Imidan^R, fenthion, Ciodrin^R, and Zytron.

Jones and Medley (1963) showed coumaphos to be an effective face fly larvicide either when fed to cattle in their grain ration or when sprayed on the pasture that the cattle were grazing. Control of face fly larvae was obtained by Ode and Matthysse (1964) when they fed dairy cows zinc oxide, fenthion, barthrin, dimethrin, 3-4 dimethyl benzyl ester of chrysanthemumic acid, coumaphos, ronnel, and Bay 22408.

Drummond (1963) and Drummond, Whetstone, and Ernst (1967) reported promising feed-additive larvicides included Bay 37341, Bay 37342, chlorfenvinphos, famphur, Imidan, fenthion, R-3828, bromophos, and Rabon.

From the screening work reported in this section one of the most promising insecticides was coumaphos. Knapp (1965) fed this compound as 2 percent of a salt mixture to pastured steers and, from a bioassay, reported 100 percent mortality of face fly larvae in the feces. However, control of adult face flies and horn flies was reported to be erratic. Similar results were obtained by Wallace and Turner (1964) when cattle were fed a salt mixture containing 5.5 percent ronnel.

Miller, Gordon, Morgan, and others (1970c) found coumaphos to have promise as a feed-additive larvicide against the house fly, but showed in another study (Miller[3/]) that ronnel was ineffective against house fly larvae, tended to be unpalatable to cattle, and was detected in their milk.

Present State of Larvicides for Fly Control

Thus far in this review I have given a brief history of the testing that has been done in an attempt to identify insecticides and other compounds which have larvicidal action against various fly pests associated with cattle and poultry manure.

Registrations for pesticides formerly granted on a "zero tolerance" or a "no-residue" basis were required to be replaced by a numerical tolerance after December 31, 1970. To accomplish this a 3-year period was provided for the registrant to develop the data to establish the numerical tolerance. During this period the registrations were permitted on an "extended" basis. As of the time of the publication, February 1971, a final determination had not been made on the registrations shown in table 2 as "extended." No use of these pesticides as larvicides for fly control should be undertaken without determining the status of registration before their use.

Most of the pesticides indicated in table 2 are organophosphorus insecticides.

The chlorinated hydrocarbon insecticide (dieldrin) may be used less in the future because of its persistency. There is one rather striking feature shown in table 2 - that is that no compounds are cleared for feed-additive use with poultry and only one has clearance for use with lactating dairy cattle. This is true even though as previously discussed there has been a great deal of research to identify insecticides which can be used as feed-additive larvicides. Even though the feed-additive approach is less efficient than adding insecticide directly to the manure, because of loss of insecticide in the digestive tract, it is ideally the method of choice for several reasons. The first of these is the relative simplicity in mixing an insecticide into a poultry ration or the concentrate portion of a ration for dairy cattle. Another possible way to feed a larvicide is by incorporating it into a salt mixture or block. In this way the insecticide appears in the feces well mixed and ready for larvicidal action. Secondly, mixing with the feed eliminates the cost of having expensive spray equipment, and the labor needed for spraying the larvicide directly on the manure. Another advantage of the feed-additive approach is that manure from cattle on pasture may be treated, which cannot feasibly be done by applying insecticides directly to the manure. The question is then, why aren't there more registrations for feed-additive

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[3/] Miller, R. W. Effectiveness of ronnel as a feed-additive larvicide for fecal house fly control. Unpublished.

use? Besides the ability of an insecticide to kill fly larvae, a good feed-additive larvicide must have several additional characteristics. These characteristics include the ability of a compound to pass through the digestive tract of an animal and appear in the feces in an amount sufficient to kill larvae of the fly species in question. The compound must be palatable and have no detrimental effect on the animal to which it is fed. In addition, neither the original compound nor any injurious metabolites must appear in the tissue, milk, or eggs. Few insecticides have all of the above characteristics. For registration purposes, the proof of these characteristics rests with the insecticide manufacturer, and studies to determine the safety and efficacy of an insecticide are expensive, especially with large animals.

At the present time coumaphos is the only insecticide registered for commercial use as a feed-additive larvicide for both beef and lactating dairy cattle. Miller, Gordon, Morgan, and others (1970c) have shown that when lactating dairy cows were fed coumaphos at levels between 11 and 144 p.p.m. of the total ration air dry matter, the concentration of coumaphos and metabolites in the wet feces ranged from 0.85 to 7.08 p.p.m.

Another organophosphorus insecticide which shows promise as a feed-additive larvicide is Rabon, which is described as a nonsystemic phosphate insecticide with a high level of activity to insects and low hazard to warm-blooded animals. The oral LD 50 for rats is 4,000-5,000 mg./kg.

Miller, Gordon, Bowman, and others (1970b) fed a 75 percent wettable powder formulation of Rabon to lactating dairy cows at levels of between 11 and 49 p.p.m. of the air dry ration. At these levels, the concentration of Rabon in the feces was between 0.03 and 0.09 p.p.m. of the wet feces. At levels above 30 p.p.m. Rabon in the diet larvicidal activity against non-resistant house flies was high. No Rabon residues[4/] were detected in the milk of cows on these experiments nor in other experiments when cows were fed up to 108 p.p.m. of Rabon.

In a field trial Miller, Drazek, Martin, and Gordon (1970a) fed an encapsulated formulation of Rabon to dairy cattle at a level of 64 p.p.m. (actual Rabon) of the air dry ration. This treatment caused a 94 percent reduction of fly larvae in field manure piles as compared to non-treated manure piles. In this trial the concentration of Rabon in the manure was approximately 3 p.p.m. The persistency of Rabon in the manure piles was not determined.

Encapsulated Rabon has been tested as a feed-additive larvicide with poultry. Good control of <u>Fannia</u> species was obtained when hens were fed 400 p.p.m. Rabon (Shell Chemical Company, 1970). The reason more Rabon must be fed to hens than to cattle appears to be due to the alkalinity of poultry droppings. The hydrolytic half-life of Rabon at a pH of 9.9 is 37 hours as compared to 7,200 hours at a pH of 1.1.

[4/] Less than 0.01 p.p.m.

Because of these encouraging results with Rabon as both a cattle and poultry feed-additive larvicide, research on this compound for feed-additive larvicidal use will be continued.

TABLE 2.--Insecticides with registrations for larvicidal use on animal manure[1/]

Compound	Type registration								
	Poultry			Beef Cattle			Dairy Cattle		
	NF[2/]	Extended[3/]	FA[4/]	NF[2/]	Extended[3/]	FA[4/]	NF[2/]	Extended[3/]	FA[4/]
Calcium arsenate	X	--	--	--	--	--	--	--	--
Phenothiazine	--	--	--	--	X	X	--	X	X[5/]
Dieldrin	X[6/]	--	--	--	--	--	--	--	--
Dichlorvos	--	X	--	--	X	--	--	X	--
Diazinon	X	--	--	X	--	--	--	X	--
Dicapthon	X	--	--	--	--	--	--	--	--
Zytron	X	--	--	--	--	--	--	--	--
Dimethoate	X	--	--	X	--	--	X	--	--
Ronnel	--	X	--	--	X	X	--	X	--
Trichlorfon	X[6/]	--	--	--	--	--	--	--	--
Rabon	X	--	--	X	--	--	X	--	--
Coumaphos	--	--	--	--	--	X	--	--	X

1/ Data supplied by Pesticide Regulations Division, formerly with ARS, USDA, now with Environmental Protection Agency.

2/ Insecticides checked in these columns can be applied directly to manure, however, the manure cannot be used on food crops.

3/ Insecticides checked in these columns can be applied directly to manure and the manure can be used on food crops until February 1971.

4/ Insecticides checked in these columns can be fed to the species indicated. With the exception of coumaphos, these registrations are valid only until February 1971.

5/ Nonlactating dairy cattle only.

6/ Battery poultry houses only.

Summary and Conclusions

Flies are definitely a problem around domestic animal manure. Although a great deal of research has been conducted to find suitable feed-additive larvicides for fly control around poultry and cattle manure, no insecticides are registered for commercial feed-additive use with poultry and only one has a registration for use with lactating dairy cattle. Three insecticides have registrations for feed-additive use with beef cattle. The current registration status of two of these pesticides is not clear. Twelve insecticides, nine of which are organophosphorus compounds, are registered for use as larvicides to be applied directly to poultry manure and/or cattle manure. Of these twelve compounds eight have the restriction that manure containing these insecticides is not to be used on crops grown for human consumption. The registrations on the other four are at the present time (February 1971) subject to further review.

These restrictions indicate that a small amount of insecticide could appear in manure that is to be refed to animals. However, from data we have obtained in feed-additive larvicide trials it appears that even if a small amount of an organophosphorus insecticide were consumed, it would probably be metabolized and excreted and would not appear in the milk, eggs, or tissues of animals so fed.

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